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UCRL-CONF-207358

Friction of LX-04

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October 20, 2004

Defense Exchange Agreement Meeting - 1671
Picatinny, NJ, United States
November 19, 2004 through November 21, 2004

Friction of LX-04*

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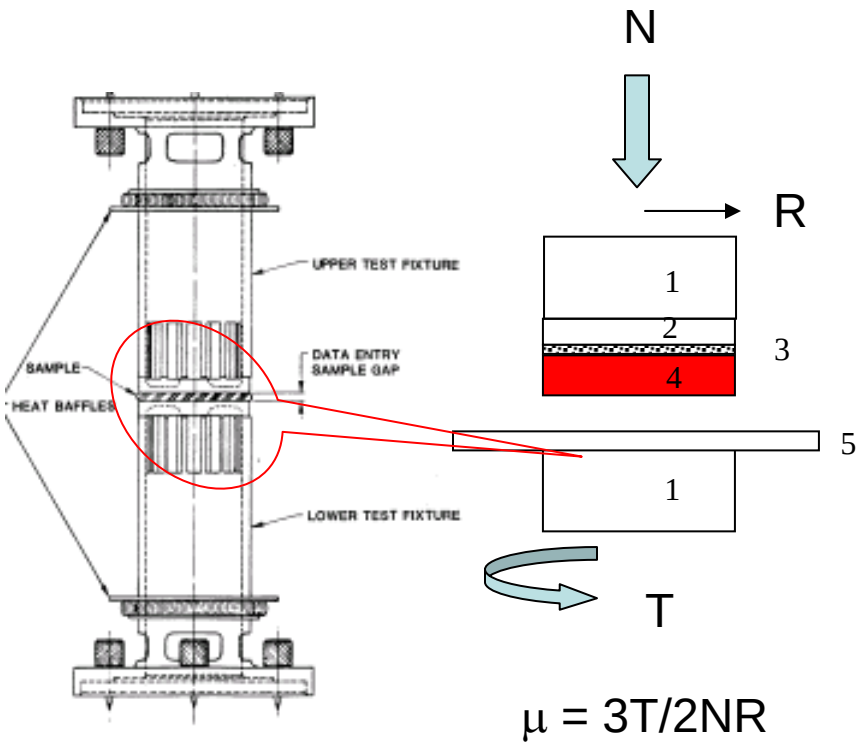
Presented at:
DEA-1671 Meeting
Picatinny, NJ
19-21 October 2004.

*This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Measurements are made on an RMS 800 with parallel plate fixtures.


UPPER TEST FIXTURE
SAMPLE
HEAT BAFFLES
DATA ENTRY
SAMPLE GAP
LOWER TEST FIXTURE

$\mu = 3T/2NR$

1. Upper fixture
2. Removable Al plate
3. Silicone cushion & adhesive
4. HE or mock cylinder
5. Material for friction against HE
6. Lower fixture

Where μ is the coefficient of friction T is the torque,
N is the normal force and R is the radius of the explosive cylinder

Method of measurement:

- RMS-800 is strain control instrument – stress is measured
  - Measure the distance to just touch the two surfaces.
  - Start the experiment with the surfaces separated (lower plate turns)
  - Run the surfaces together along the z direction (increasing N) to some deformation of the foam, typically 0.010 mm.
  - Record the torque and normal force for ~ 1 minute (until nearly constant values are reached).
  - Remove normal force prior to end of the test to reestablish zero.
  - Increment the temperature and equilibrate for 2 minutes
- Initial test development was done with this mock
  - Roughness of SS comparable to pressed mock but smoother than machined mock (RM-04-BR) by about 4x.
  - RM-04-BR is Viton and Cyanuric acid : 15/85 – very similar to LX-04 (HE of initial interest)

EMC
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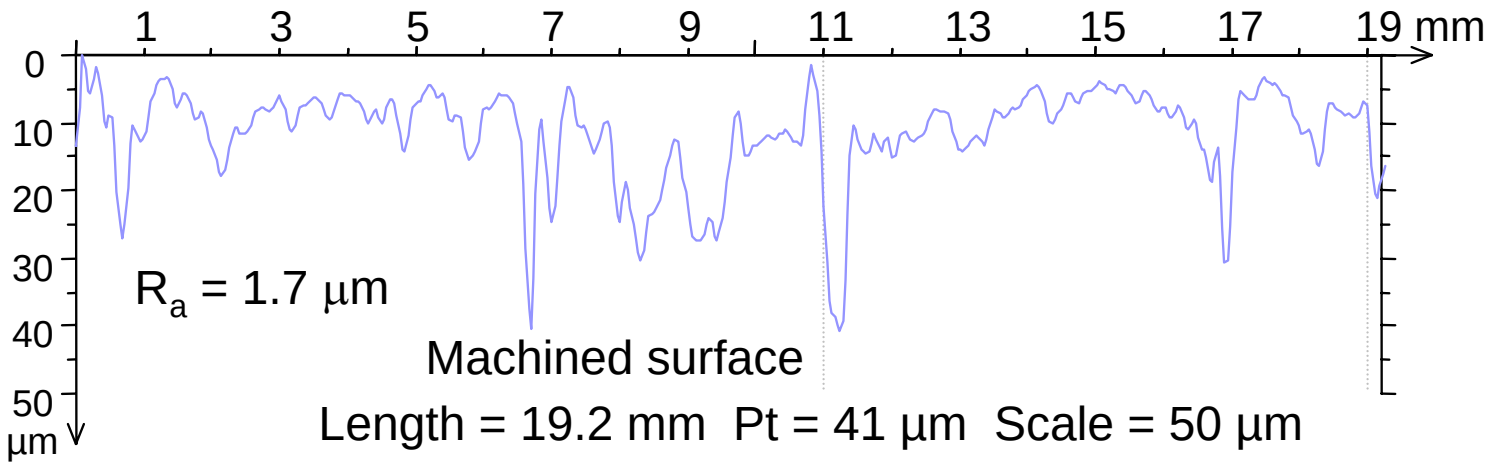
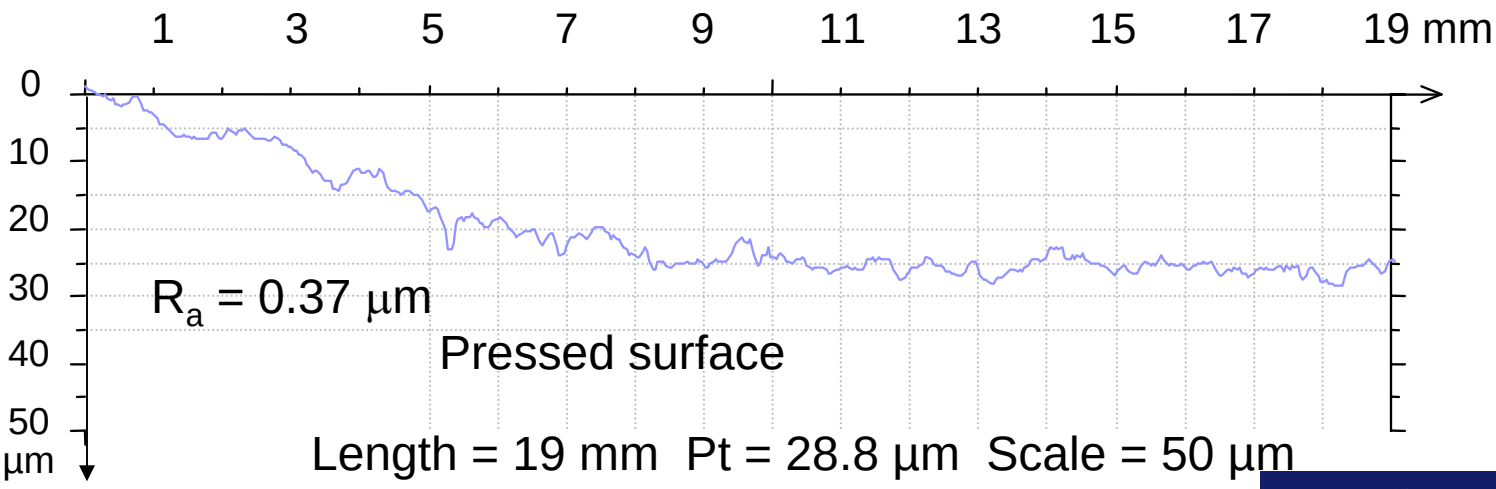
Surface profiles for machined mock was much rougher that pressed RM-04-BR

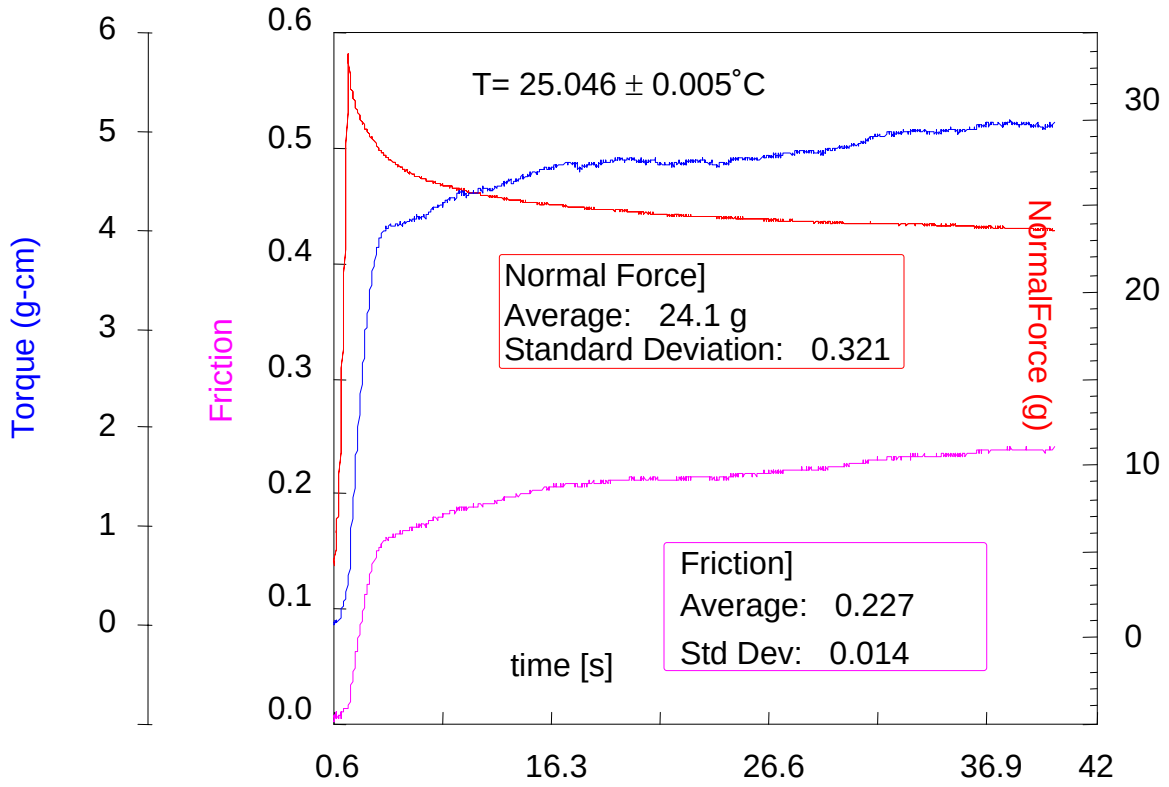




Curvature of pressed sample may be due to flash

Friction coefficients for RM-04-BR with smooth or rough surface on SS at low NF & 25°C were similar.

- Typical trace:
  - Compress HE
  - As foam relaxes
  - Torque increases
  - Normal force decreases
- Friction gave no static peak in RM-04-BR
- In 10 s normal force levels out (24 ± 3g)
- Similarly Torque levels out (5 g-cm)
- Dynamic friction = 0.23 at 25°C
- Temp was well controlled



What is the effect of increased normal force?

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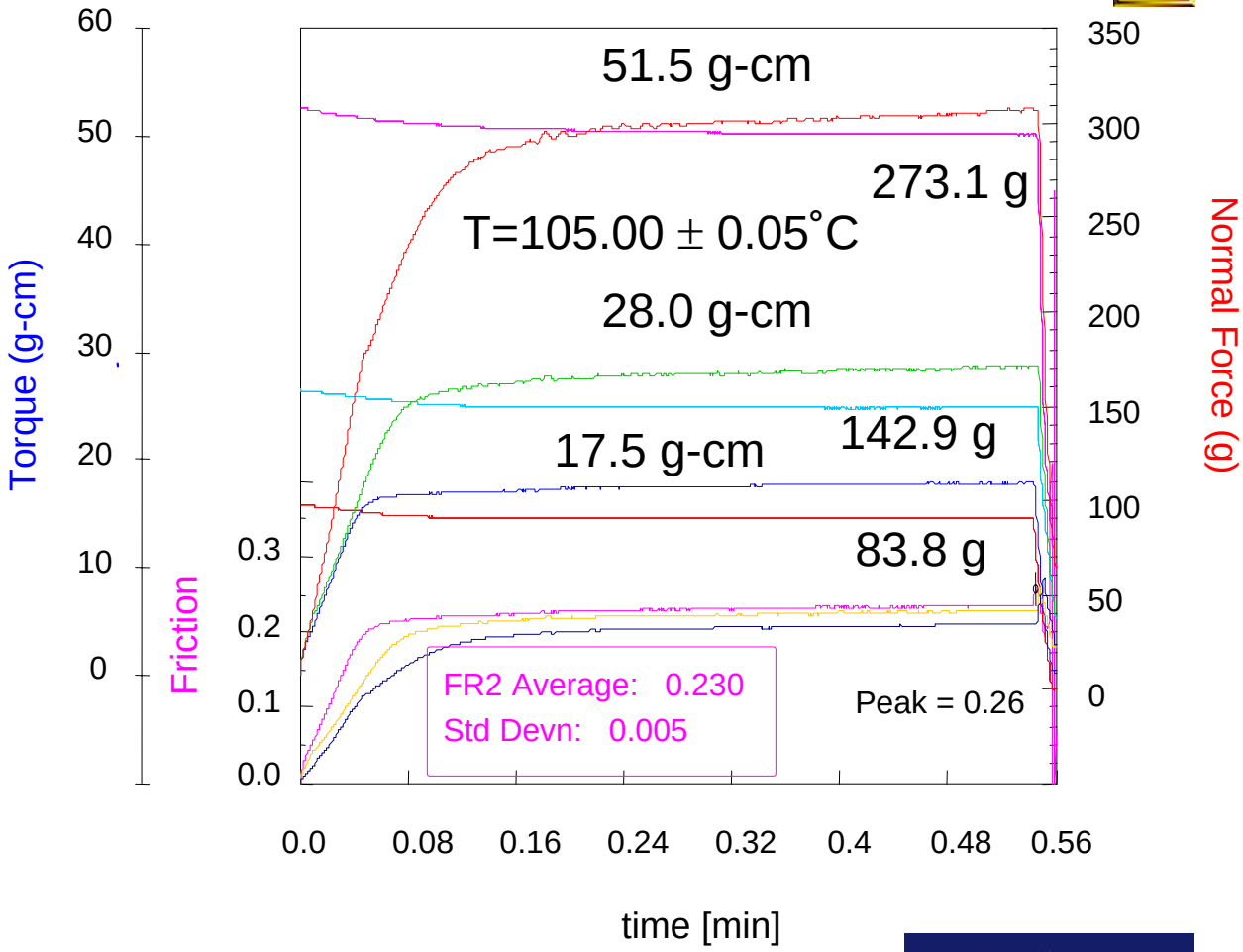
Increasing normal force only slightly effected the coefficient of friction as seen at 105°C below

- Sample was compressed 0.02 to 0.04 mm to achieve different normal forces
- Friction coefficient was only slightly effected
- Peak at the end of the friction measurement may be bending during removal of normal force?

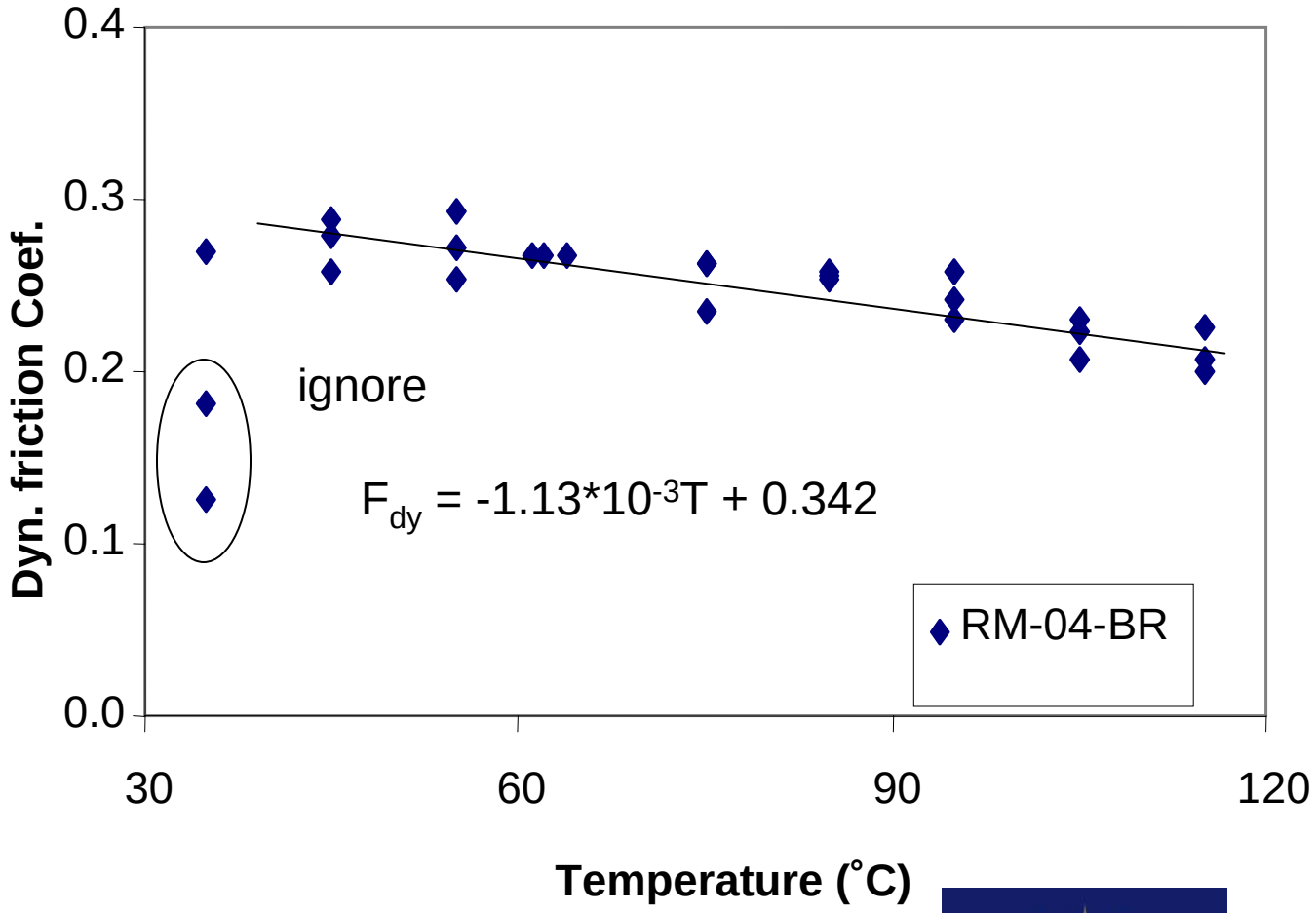


Effect of varying the NF as f(T) was small; no high P data currently possible. (0.1 < P < 1 psi)

EMC Energetic Materials Center

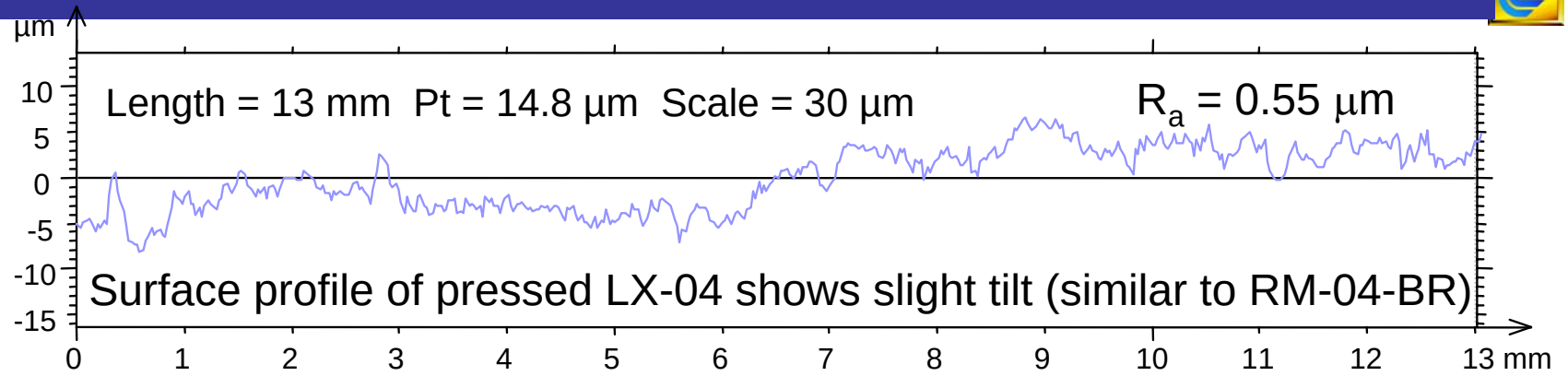
Friction of Stainless on machined surface of RM-04-BR decreased slowly up to 115˚C.

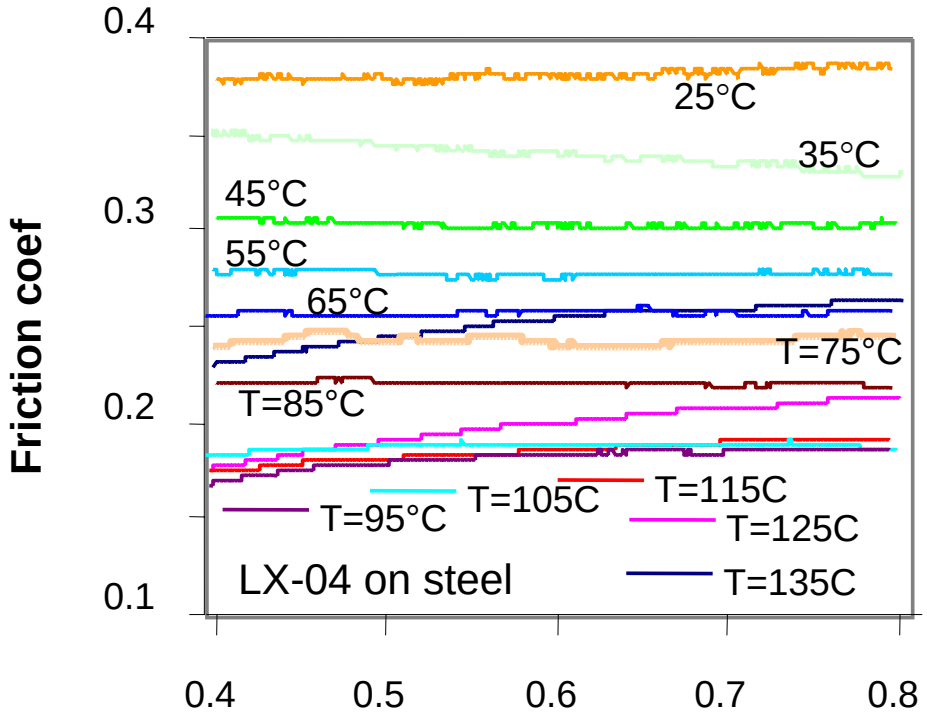
- Highest NF gave slightly higher μ
- Decrease in μ with temperature was small
- Anomalous data at ambient was observed & ignored
- Linear fit ignores any rate or NF effects or transitions in Viton



Ready to do live HE: LX-04

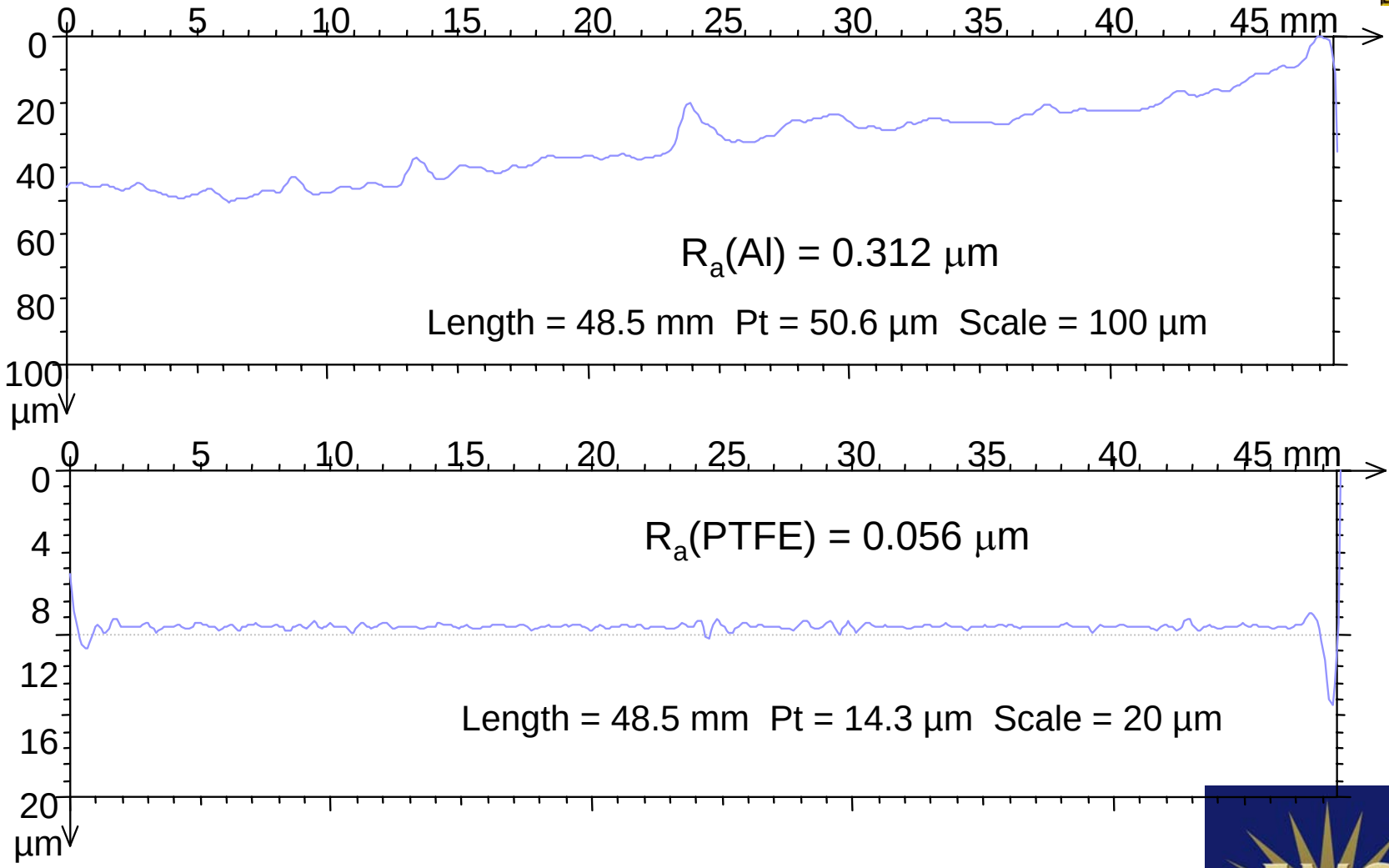
Compression molded LX-04 had an R_a = 0.55 μm



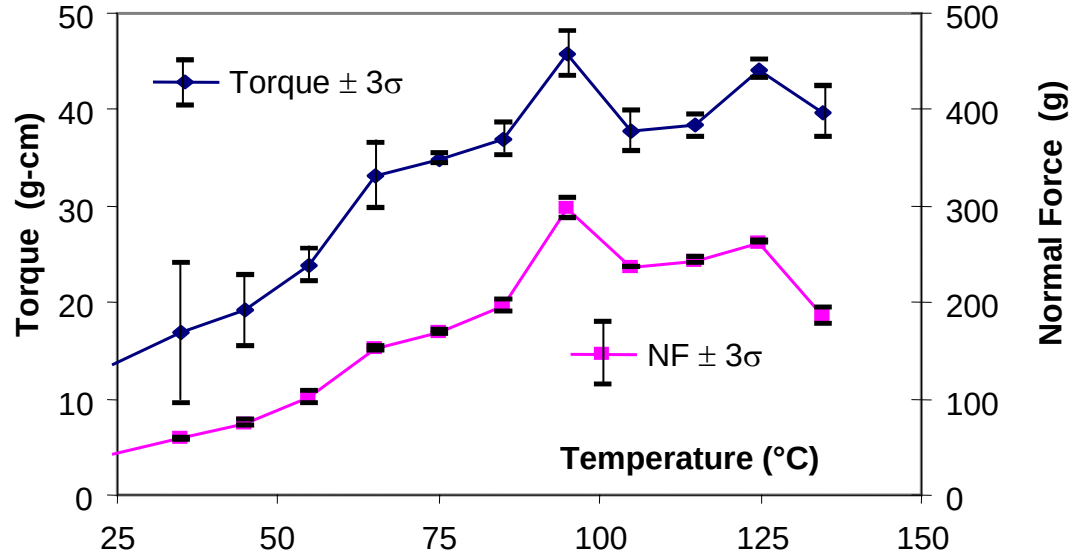


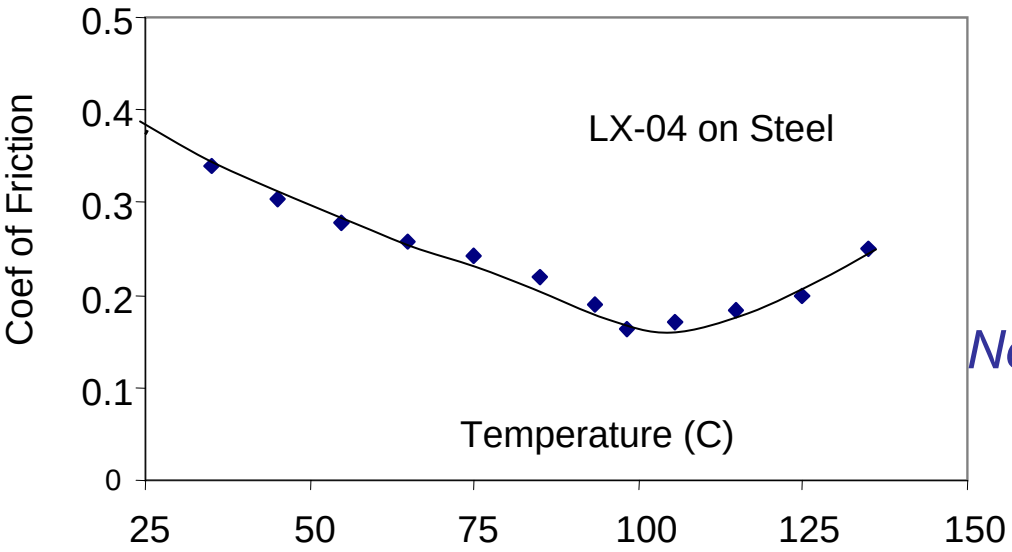
- LX-04 R = 1.264 cm; ρ = 1.869 g/cc
- Against SS, μ(LX-04) decreased with increasing T until about 95°C
- From 95<T<125°C μ was constant at ~0.17
- Anomalous increase in μ above 125°C

Surface profiles of Aluminum and PTFE were measured in preparation for friction testing



Friction coefficient of LX-04 on Steel decreased to a minimum at about 100˚C

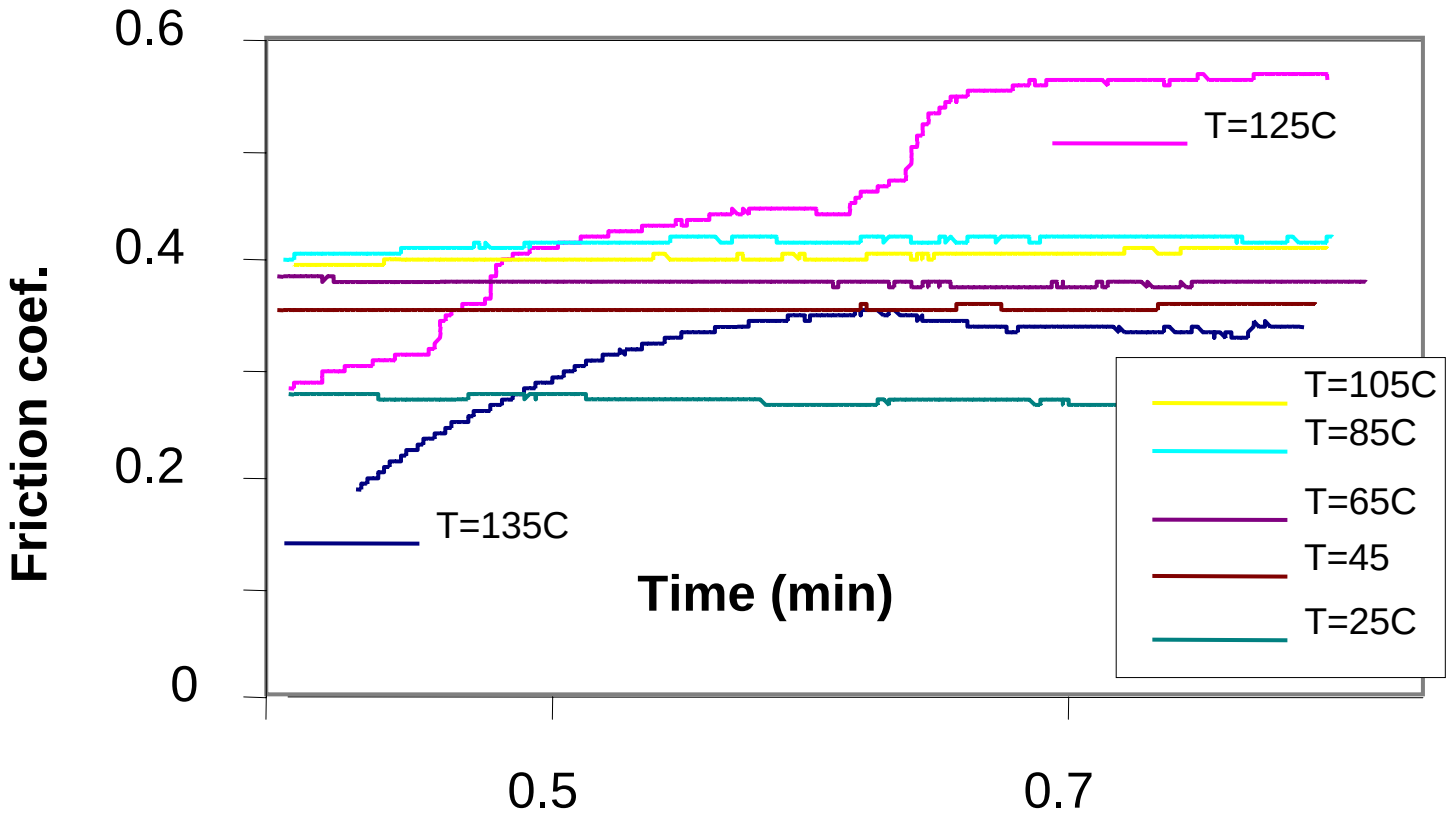




- Normal Force tended to increase with increasing Temperature.
- Torque follows normal force.
- Friction is initially reduced dramatically with increasing temp.
- Friction minimum of 0.18 from 95 <T< 115˚C
- Friction increased above 115˚C

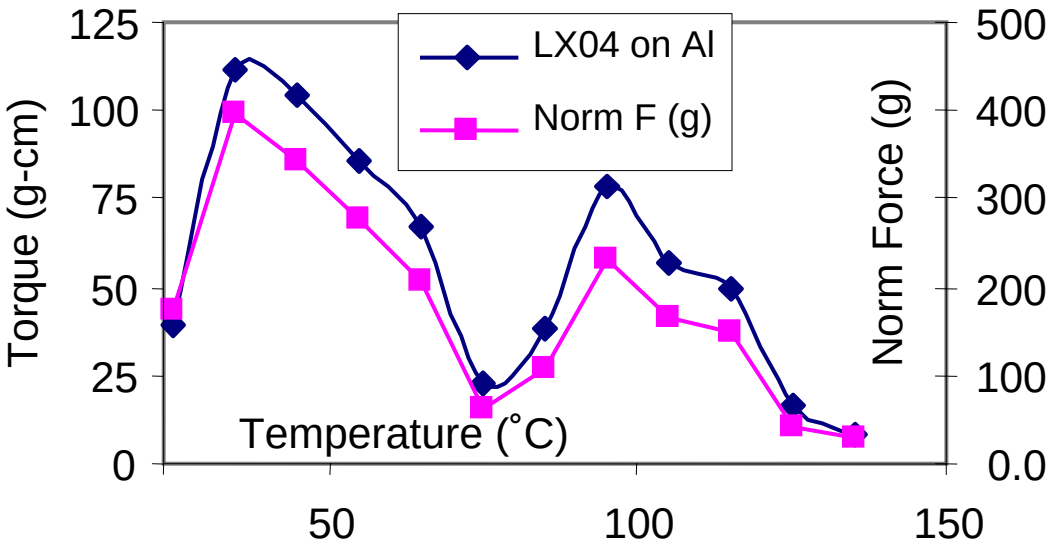
Next looked at Aluminum/LX04

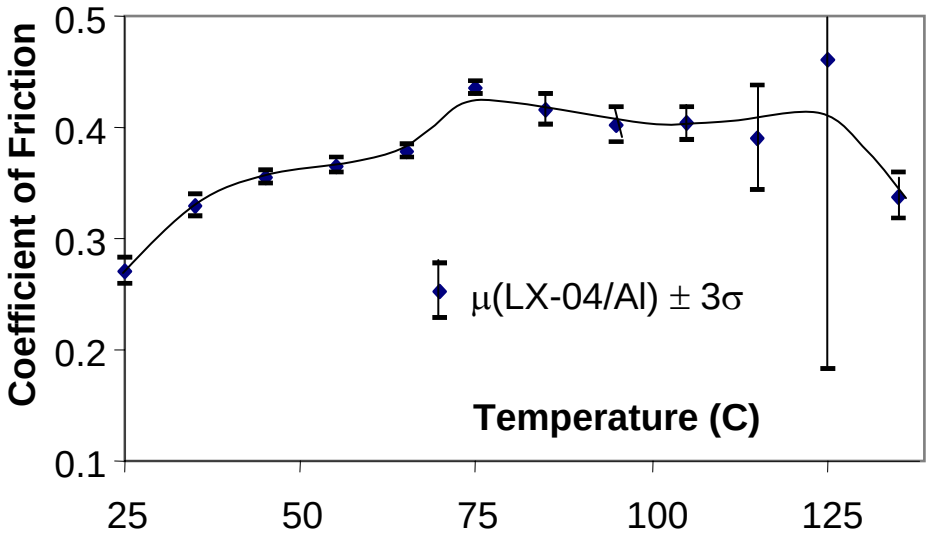
Friction of LX-04 on aluminum gave constant dynamic coefficients with time up to 125˚C



Above 125°C there may be interactions between Viton & Al

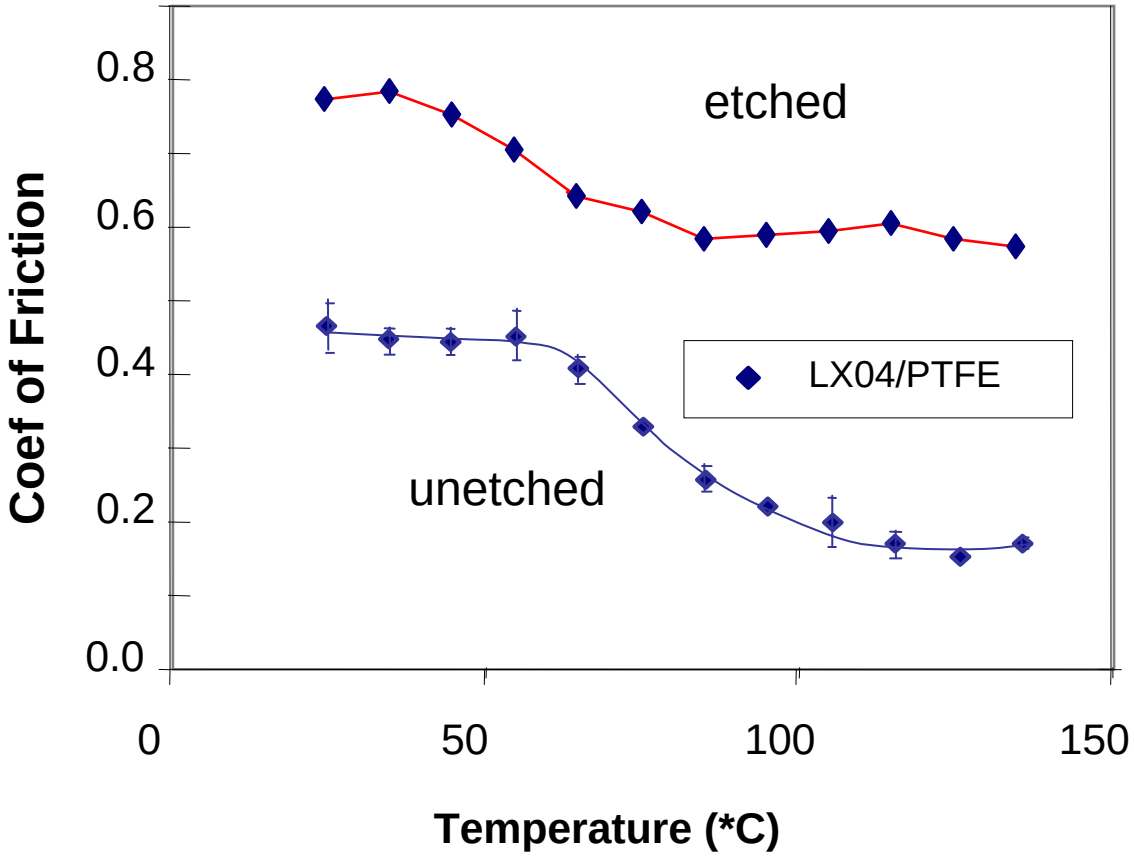
LX-04 friction on Aluminum increased with temperature





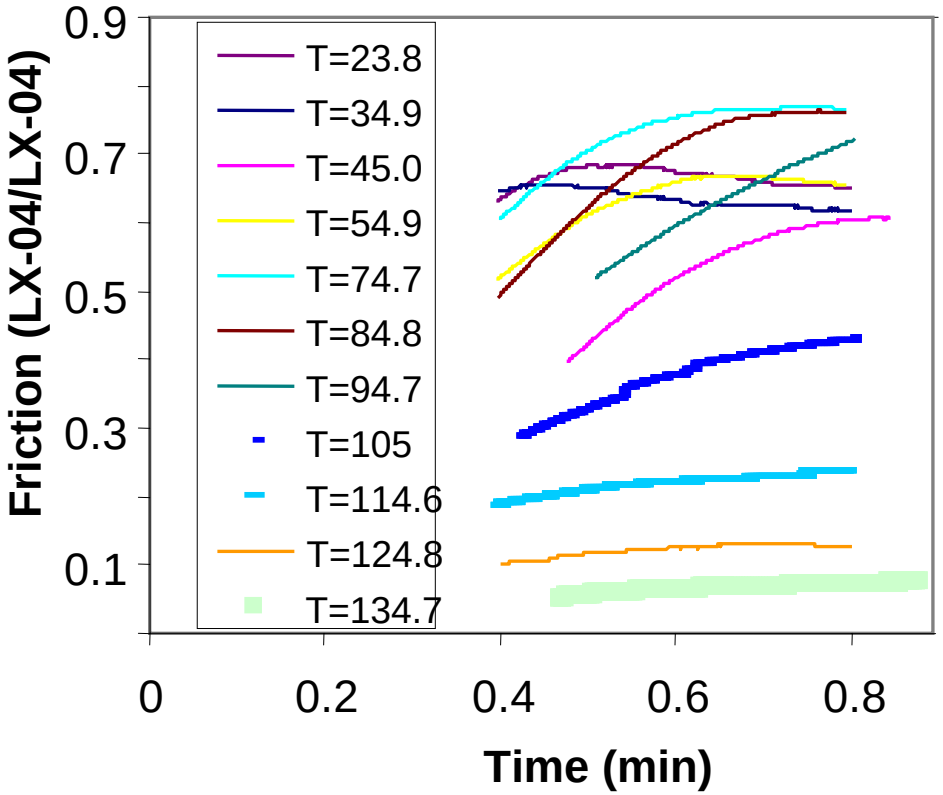
- Normal Force tended to decrease with increasing temperature.
- Torque follows normal force.
- Friction is increased slowly with increasing temperature.
- Friction varies from about 0.28 at ambient to about 0.4 at elevated temps.
- Viton is known to react with Aluminum at high normal force.

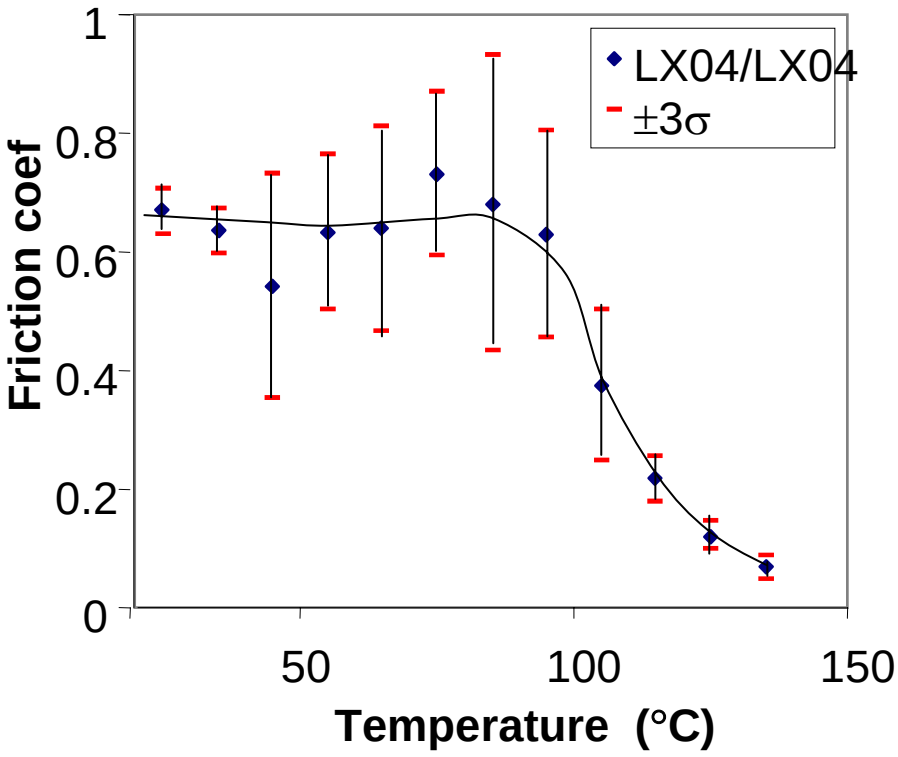
Friction of LX-04 on PTFE was higher than expected but decreased with increasing temperature



- PTFE is not an effective lubricant for LX-04 until about 80°C.
- μ is nearly constant at 0.45 up to 65°C, then drops off and levels out at 0.15 above 100°C
- Etched PTFE gave much higher μ.
- Curve shapes are similar.

μ(LX-04) on LX-04 drops off dramatically above 100°C.





LX-04 on itself shows viscoelastic behavior ($\mu \neq$ constant).

Viton has a very small amount of crystallinity.

Further work:

- *Evaluate rate effects*:
  - current rate – 0.01 sec^{-1} could easily go higher and somewhat lower
  - Hoge found maximum in μ at intermediate rates (v = 2 in/s)
- *Evaluate roughness effects*:
  - Optical profilometer can determine R_a surface finishes
  - Differences between machined and pressed (finer finish greater μ)
- *Effect of normal force* (limited by transducer to 500g) could add weights below transducer. Torque range (2000 g-cm) should accommodate 3 Kg.
- Can you generate "master curves" of friction as a function of t, T? other?
- Present results in a simple tabular format with recommendations for use.
- *Other HE of interest*: currently working on LX-17 and PBX 9404.
- Viton series of: LX-04 (done), LX-10, LX-11, LX-07;
- PBX 9501; LX-14; XTX-8004; LX-13; PBX 9407 (RDX); LX-16 (PETN); LX-18 (HNS); LX-19 (CL-20)…
- *Other substrates of interest:*